

Phase I Testing Summary

(Field Evaluation of Veeder-Root Discriminating Sensors)

Introduction

Sensors are used in a variety of places within a UST system to detect a release of product. For double-wall systems, they are either located inside the secondary containment (sumps and under dispenser pans) or in the space between the primary and secondary containment of the tank or piping, known as the interstitial space. Field experience has shown that due to numerous design, installation, and maintenance issues these areas are often not kept clean of water intrusion or excessive condensation. This has led the industry to introduce sensors that are capable of differentiating between water and hydrocarbons. These sensors are referred to as “discriminating sensors.”

Discriminating sensors can provide distinct alarms for water or product. Some even offer distinct alarms for low and high levels of water. Depending on how the control panel is programmed, a product or water (low or high level) detection can activate a warning, alarm, or pump shutdown. Typically, sensors are programmed to provide a warning when water is detected, which still allows the UST system to operate. Product detection is typically programmed to activate a fuel alarm, and may also automatically shut down the pump.

There are two basic approaches to discriminating sensors, as described in the following paragraphs. One approach to discriminating sensors is to combine two or more sensing elements into a single unit (See Figure I). This approach is well suited for sumps where surface water is prone to leak in, presenting the possibility of product floating on water. Sensing elements (most often a float switch) are used to detect low and high liquid levels. If the level rises above a preset point, the sensor notifies the operator by activating an alarm or warning message on a control panel. A hydrocarbon-sensing element (such as a product permeability sensor) is also incorporated to detect the presence of product. The combination of these multiple sensing elements into a single unit makes a discriminating sensor able to determine the presence of water versus hydrocarbons. There are several combinations of detection mechanisms that may be incorporated in a single unit to produce a discriminating sensor.

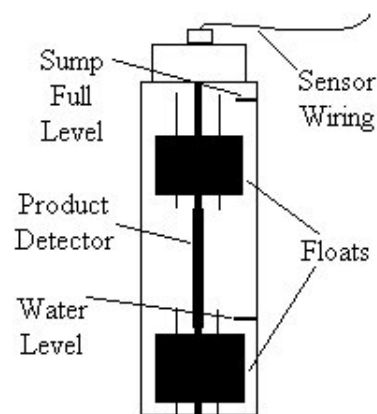


Figure I - A typical multi-element discriminating sensor with float switches and a product solubility element.

The second type of discriminating sensor uses only one detection mechanism, but is able to discern between product and other liquids based on some specific property of the liquid. Some adsistor, capacitance change, electrical conductivity, fiber optic chemical, and thermal conductivity sensors are sophisticated enough to distinguish between product and water.

Purpose of the Project

This report is based on testing performed only on discriminating sensors manufactured by Veeder-Root, as they are the most prevalent in California. We initiated a field study of discriminating sensors in response to local agency concerns that some of these sensors did not appear to operate properly when annual maintenance certification and inspections were conducted. Particular items of concern brought to our attention by local agency inspectors were:

- The inability of discriminating sensors to detect a layer of hydrocarbon-based product (i.e. gasoline) floating on top of water and to properly distinguish between water and product;
- The inability of polymer-based hydrocarbon detecting elements to alarm in a reasonable amount of time; and
- The inability of polymer-based hydrocarbon detecting elements to return to effective operation (recover) after exposure to hydrocarbons.

While this project was initially designed to address the aforementioned local agency concerns, we enlisted the help of discriminating sensor manufacturers and local agency inspectors to expand the scope of the study. The scope of the study included:

- Evaluating the functionality of discriminating sensors used in California (in response to the above listed concerns of local agency inspectors);
- Checking the adequacy of field-testing procedures for discriminating sensors (or work with manufacturers to develop field-testing procedures if they are not already available);
- Determining if discriminating sensors in the field perform consistently with the specifications outlined in their third-party evaluations; and
- Determining if the third-party evaluation protocol currently used is suitable for the sensor types tested using that protocol.

Coordination of the Field Testing

Since the focus of the testing was on the performance of sensors in the field, it was necessary to conduct testing at operating facilities where the sensors are installed. Three local agencies representing a cross section of California's UST population local regulatory governments volunteered to assist with this project. The City of Santa Ana, City of Santa Monica, and City of Oakland helped us to identify facilities within their jurisdictions that were using Veeder-Root discriminating sensors. In order to minimize the impact on owners, operators, and local agencies, we scheduled our field testing to coincide with the required annual inspections. The maintenance contractor performed the testing for the sensors while completing all the other scheduled annual certification work. Manufacturer's representatives were on hand to observe the testing, assist with the advanced setup and diagnostic features of the sensor control panel, and to answer technical questions.

Testing Procedure

In order to test the sensors during this evaluation, Veeder-Root prepared a draft testing procedure. We reviewed and provided comments on the draft test procedures, which were then

modified by Veeder-Root and re-submitted as a second draft. The second draft was the testing procedure used in our field evaluation. Modifications were made throughout the study, as deemed necessary by our staff on site. Modifications were included to minimize station downtime, and to test possible improvements to the protocol (such as the cleansing of sensors in white gas¹ to accelerate recovery of polymer strips.)

The basic test procedure was to immerse the discriminating sensor in fuel, water, or a fuel/water mixture to see if it alarmed appropriately (e.g., water and/or fuel). We modified the procedure by using a stopwatch to determine the length of time between sensor immersion and alarm, and the length of time for the sensor to recover after being removed from the liquid. We also noted the type and the depth of the liquid in which a sensor was immersed, as well as the type of alarm (fuel, water, or both water and fuel) the sensor registered.

Test procedures varied slightly between sensor models, due to differences in detection mechanisms. Veeder-Root's discriminating sensors can be classified in two general families based upon their fuel-sensing mechanisms: Ultrasonic sensors (model 794380-341), and Polymer Strip Sensors (all other models tested). Table I lists the Veeder-Root discriminating sensors tested in this study, including the mechanisms each sensor model uses to determine the presence of liquid and/or fuel, and the testing procedure used in our study.

TABLE I - Veeder-Root's Discriminating Sensors

Model Number	Application	VR Test Procedure	Water Sensing Mechanism	Fuel Sensing Mechanism
794380-320	Dispenser Pan	A	Ultrasonic	Polymer Strip
794380-350	Sump (Pump or Piping)	A	Ultrasonic	Polymer Strip
794380-322	Dispenser Pan	A	Float Switch	Polymer Strip
794380-352	Sump (Pump or Piping)	A	Float Switch	Polymer Strip
794380-360	Fiber Trench	A	Ultrasonic	Polymer Strip
794380-361	Fiber Trench	A	Ultrasonic	Polymer Strip
794380-362	Fiber Trench	A	Ultrasonic	Polymer Strip
794380-341	Interstitial	B	Ultrasonic	Capacitance Change

Data Collection

City of Santa Ana

SWRCB staff, local agency inspectors, maintenance contractors, and Veeder-Root representatives collected data for this project. Data collection began in Santa Ana in August 2000, where the local agency inspector, maintenance contractor, Veeder-Root representatives were present at each testing site. SWRCB staff was present at some of the Santa Ana sites. Veeder-Root representatives recorded the test data in Santa Ana. This data was forwarded to us for analysis. (See Table II for a summary of this data.)

¹ Since the time of testing we have heard from other manufacturers of polymer strip sensors that this practice, although common among service technicians, may have an adverse effect on the polymer strip sensor's continued functionality. SWRCB staff does not recommend cleansing sensors with white gas unless specifically instructed to do so by the sensor manufacturer.

SWRCB staff did not always witness testing in Santa Ana. Additionally, we were still refining the scope of data to be collected, testing procedures, and protocol for data collection. For these reasons, results of testing in Santa Ana were usually considered only when making general observations and conclusions in this report, not in making any specific calculations. An exception to this is test data for model 794380-341 sensors. Santa Ana test data for this model has been included in the calculations of this report, since the sample size in Santa Monica and Oakland was so small. The local agency inspector present at all Santa Ana sites furnished us with his reports on the sites equipped with model 794380-341 sensors, and this data was used in calculating pass/fail rates for that model.

City of Oakland and City of Santa Monica

Testing was conducted in Oakland and Santa Monica in October and November 2000. Local agency inspectors, Veeder-Root personnel, service technicians, and SWRCB staff were present at all facilities tested. SWRCB staff recorded all test data. Upon completion of testing, the data collected from Oakland and Santa Monica was compiled in a data table, which is summarized in Table III.

Table II - Summary of Veeder-Root Test Data from Santa Ana*

Dates of Testing	August 21 st -25 th , 2000
Number of Facilities Tested	8
Number of Sensors Tested	(model 794380-208) = 18 (model 794380-320) = 3 (model 794380-341) = 13 (model 794380-350) = 26 (model 794380-352) = 5 (model 794380-362) = 1 (model 794380-40x) = 10
Total Number of Sensors Tested	76

*Detailed test information not available for Santa Ana facilities

Table III - Summary of Test Data from Oakland and Santa Monica

Number of Facilities Tested	18
Number of Sensors Tested	(model 794380-320) = 2 (model 794380-322) = 1 (model 794380-341) = 6 (model 794380-350) = 8 (model 794380-352) = 49 (model 794380-360) = 1
Total Number of Sensors Tested	67
Pass/Fail Data for Model 794380-341	4 passes, 2 failures
Range of Response Times in Fuel and Fuel/Water Mix (794380-350)	3:26 to 42:50 (min:sec)
Range of Recovery Times in Fuel and Fuel/Water Mix (794380-350)	19:49 to 70:40 (min:sec)
Range of Response Times in Water (794380-352)	2 to 18 seconds
Average Response Time in Water (794380-352)	8 seconds
Range of Response Times in Fuel and Fuel/Water Mix (794380-352)	4:59 to 12:10 (min:sec)
Average Response Time in Fuel and Fuel/Water Mix (794380-352)	7 minutes, 15 seconds
Range of Recovery Times in Fuel and Fuel/Water Mix (794380-352)	0:27 to 52:29 (min:sec)
Average Recovery Time in Fuel and Fuel/Water Mix (794380-352)	17 minutes, 26 seconds

Discussion

Since the operating mechanism and testing procedure of the Veeder-Root model 794380-341 sensor are different than all the other sensors in our study, it is reasonable to divide the “discussion” section into two parts: one part for the 794380-341 (ultrasonic mechanism), and one for all of the other sensors in our study (polymer-strip mechanism).

Ultrasonic Mechanism (Veeder-Root Model 794380-341)

Our testing showed the 794380-341 interstitial fiberglass tank sensor performed unsatisfactorily. Eleven of 20 model 794380-341 sensors failed when tested in the field². Usually, the sensors detected the presence of liquid, but were unable to discriminate between fuel and water. Veeder-Root determined the failures are due to a faulty solder joint within the sensor, and is planning to make design changes to eliminate the problem. Since the sensor cannot reliably discriminate between fuel and water, Veeder-Root intends to reclassify the current 794380-341 sensor as non-discriminating³.

When testing the 794380-341 sensors in Santa Ana, we observed that they often came out of the tanks wet. The moisture was a clear, odorless and somewhat gooey film. When the film dried, it became milky white⁴. There appeared to be moisture in the interstitial spaces of the tanks these sensors are monitoring, but not enough to activate an alarm. Follow-up information from Santa Ana indicates that these sensors had to be cleaned before they would alarm properly when tested, and that this is a common occurrence observed by inspectors during routine sensor field certifications.

Polymer-Strip Mechanism (Veeder-Root Models 794380-320, 794380-322, 794380-350, 794380-352, 794380-360, 794380-361, and 794380-362)

The polymer-strip discriminating sensors consist of three separate sensing elements. The low and high liquid detectors are float switches or ultrasonic sensors depending on the model. The product-sensing element is a polymer strip that absorbs hydrocarbons. The strip is imbedded with small particles of conductive material (See Figure II). As the strip absorbs hydrocarbons, the material expands and the strip becomes less conductive (e.g. the resistance rises). When the resistance reaches a certain level (for Veeder-Root sensors this is set at approximately 250 kΩ to 500 kΩ) an alarm is activated.

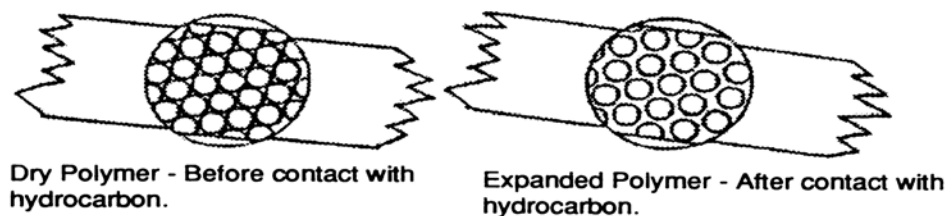


Figure II – Polymer strip used in discriminating sensors

² Includes data supplied by the local agency inspector present at Santa Ana test sites.

³ Veeder-Root has completed reclassification of the model 794380-341 sensor since this summary was originally prepared.

⁴ The local agency inspector present at these facilities was concerned that the liquid may include resin or adhesive used in construction of the fiberglass tanks where these sensors are installed.

The low and high-level liquid sensors proved to be generally effective. They typically activated a liquid alarm in less than the third-party specified time. On the few occasions that a sensor did not respond properly, the problem was usually diagnosed as faulty wiring or improper programming of the console and not a design problem.

While our field-testing showed the low and high level liquid sensors to be effective, several issues concerning the polymer strip were raised which may be cause for concern and further investigation. Other issues, such as control panel configuration and testing protocols, were also brought to light in the course of field-testing. The following paragraphs discuss these concerns in detail.

1. Response and recovery times of the polymer strip element when exposed to fuel were sometimes excessive, and not always consistent with third-party claims. Primary concerns include the length and variation of response and recovery times, as discussed below:

(a) Length of Response Times

The fuel alarm is activated only after enough fuel has permeated the polymer strip to raise its electrical resistance to a value of 250 k Ω -500 k Ω . The time required to reach the necessary electrical resistance varied from 5 to 12 minutes, with an average of just above 7 minutes. Typically the resistance in the strip did not change appreciably for several minutes. In the event of a catastrophic leak, this response time could lead to large amounts of fuel in the dispenser pan or containment sump. As the liquid level reaches the high-level liquid sensor a high level water alarm will sound, but it could still be many minutes before the polymer strip reacts to the fuel and activates a fuel alarm. This would be a major concern if the system is not configured for turbine shutdown when the high level water alarm is activated.

(b) Variation of Response Times

With the wide variation in response times between sensors of the same model tested in the same product, it is difficult to say exactly how long a polymer-strip sensor should typically take to alarm once exposed to fuel. This makes it difficult to establish field-testing guidelines, or to determine if a sensor is actually non-functional or just slow to respond.

(c) Length of Recovery Times

Recovery times often exceeded the third-party value of 17.17 minutes. Values ranged from under 1 minute to over 52 minutes, with an average of more than 17 minutes. Like a sponge in water, the strip swells when exposed to fuel. It must completely dry out and return to its original shape in order to come out of alarm. This can take quite awhile, depending on how saturated the strip is and how volatile the liquid is. In the interest of time, our test procedure called for a minimum amount of fuel, and for the sensor to be removed from fuel as soon as it alarmed. We even experimented with removing the sensor from fuel before it had alarmed in hopes of decreasing recovery times. Even so, the recovery times were high. Although the test protocol used in this study did not include long-term immersion of sensors in fuel, it is reasonable to believe that sensors immersed in fuel for extended periods of time (as would be the case in the event of an actual leak) would take even longer to recover, or may not recover at all.

2. Response and recovery times seem to vary with weather conditions.

(a) Warm and dry vs. cool and wet conditions

Although it is difficult to substantiate with hard data due to the inconsistency of our testing procedures⁵, the polymer strips tended to respond and recover more quickly in warmer weather. We observed that sensors tested in the sun and sensors tested during dry conditions recovered more quickly than sensors tested in rainy or colder weather. This may be due to the fact that in colder or more humid weather fuel is less volatile.

(b) Very cold conditions

The correlation between temperature and response/recovery time may become a major factor at extremely low temperatures. In our field evaluation, we did not test sensors in freezing conditions, so we do not know if the polymer strips are still effective at these temperatures. Is fuel volatile enough during freezing temperatures for the sensor to absorb the hydrocarbons and go into alarm? We posed this question to Veeder-Root in a letter. Nowhere in the third-party evaluation is temperature or humidity considered. We simply do not know how effective these sensors will be in extreme temperatures.

In addition to the polymer strips, we are also concerned about the functionality of float switches in freezing conditions, especially those monitoring shallow sumps and shallow under-dispenser containment boxes. It may be possible for condensation to freeze on a float switch and render it inoperable.

3. The frequency of data transmittal between the sensor and the control console is a factor in response and recovery times.

The console (e.g., TLS 350) “looks” at the status of each sensor or leak detection element in the UST system. It cycles through each sensor and element in the system before returning to the beginning. If multiple sensors and elements are built into the programming, it may take more time for the console to return to a particular sensor. As a result, facilities with a large number of sensors may take longer to activate an alarm at the console than those with a small number of sensors.

4. Alarm Settings and Pump Shutdown Features.

Many of Veeder-Root’s polymer-strip discriminating sensors have three different types of alarms: a low liquid alarm, a high liquid alarm, and a fuel alarm.

- The low liquid alarm is triggered by a float switch or ultrasonic mechanism located at or near the bottom of the sensor housing. This mechanism will “trip” whenever it is covered with fluid. It does not discriminate between water and fuel. This mechanism activates a warning (yellow light) at the control panel.
- The high liquid alarm is also triggered by a float switch or an ultrasonic mechanism, which is located a few inches from the top of the sensor housing.

⁵ In warm weather, the thin layer of fuel used on top of water evaporated completely before the sensor alarmed. The service person conducting the test had to add more fuel several minutes into the testing, causing very long response times. Therefore the correlation between temperature and response time which might otherwise have been evident is not readily recognized.

Again, this mechanism cannot discriminate between water and fuel. This mechanism activates an alarm (red light) at the control panel.

- A fuel alarm is triggered by a polymer strip that runs the length of the sensor housing, from the bottom of the sensor to the top float switch. Unless the polymer strip detects hydrocarbons, alarms from this mechanism are considered an indication of water intrusion. This mechanism activates an alarm (red light) at the control panel.

Both warnings and alarms are designed to alert the operator that there is something wrong with the UST system. Each requires investigation, and should receive an appropriate response from the operator. Warnings and alarms may also be programmed to activate pump shut-down, which turns off the turbine so that the UST cannot operate. Pump shut-down is generally only done with alarms.

If warnings or alarms are ignored and the liquid level exceeds the height of the top float switch, the sensor no longer detects additional fuel or water entering the sump. The sensor becomes ineffective and no longer provides leak detection; therefore, pump shut down at the high level alarm is a must.

5. High Vapor Mode

Another feature of the Veeder-Root control panel is the “High Vapor Mode.” This operating mode is designed for use in areas where background levels of hydrocarbon vapors are high enough to activate the fuel alarm, even though the UST system is not leaking. This may be due to a previous release of product, or possibly the materials and adhesives used in the construction of the UST itself may release vapors. “High Vapor Mode” is a tool used to eliminate false alarms. When the console is configured in “High Vapor Mode,” the sensor will not sound a fuel alarm unless it detects both the presence of liquid and hydrocarbons. The low liquid alarm mechanism must be triggered and the resistance in the polymer strip must be high enough to trigger a fuel alarm.

Although the sensors we tested in “High Vapor Mode” seemed to be generally effective, they have not been third-party certified for operation in “High Vapor Mode” versus “Low Vapor Mode.”

6. Lack of Field Testing Procedures.

Although each manufacturer may provide its own manual of procedures for testing discriminating sensors, there are several different tests a technician can run. Some agencies require a test of the low and high liquid alarms only. Some agencies require testing the sensors in fuel and water separately. And some agencies require each sensor to be tested in fuel, in water, and in a fuel/water mixture.

Based on the results of our field testing, we determined that it is necessary to periodically test all sensors in fuel. Even though the consoles are designed to run diagnostics on the sensors, the consoles do not always recognize problems with sensors or their wiring. We encountered two or three sensors that were either not programmed properly or had wiring problems. These programming or wiring problems were only discovered through

physical testing of the sensors in fuel. We might also benefit from testing sensors in a water/product mixture, since it simulates more accurately conditions encountered in parts of the UST system that are prone to water intrusion.

7. Degradation of Polymer Strips

Our testing provided no conclusive information as to the long-term reliability of polymer-strip sensors in harsh environments, or after repeated/prolonged exposure to hydrocarbons. Results of testing showed a wide variation in the response and recovery times for the polymer strip sensors. In many cases these times exceeded the third-party specifications.

The manufacturers of polymer strips claim the strips are testable and reusable, but each time the strip comes in contact with fuel, it apparently either retains some of the volatile compounds within its material or its elasticity is compromised after repeated/prolonged hydrocarbon exposure. Once exposed to fuel, the sensor is no longer “good as new.” Eventually, the sensor will degrade so much that either it may not recover from an alarm condition (the resistance will not drop to the point that it comes out of alarm), or the probability of false alarms will be very high. We do not know how many testing cycles a sensor can reasonably accommodate.

8. Volatility of Stored Product

The polymer strip is most readily activated by volatile hydrocarbons, with unleaded fuel and white gas producing the most rapid responses. The sensors also recovered from exposure to these fuels fairly consistently. Diesel fuel would activate an alarm, but not nearly as quickly as the more volatile unleaded fuel. Recovery times were very slow. Veeder-Root suggested cleaning sensors exposed to diesel fuel with white gas in order to speed up recovery. Technicians told us that sensors exposed to diesel must often be air-dried for days, and even then, sometimes never recover.

Although we encountered some waste oil UST systems being monitored by Veeder-Root discriminating sensors, we did not test the sensors in waste oil. Veeder-Root’s sensors are not third-party evaluated for use in waste oil applications. We are concerned that waste oil may not be volatile enough to trigger an alarm from polymer strip sensors.

9. Third-Party Protocol is Inappropriate for Polymer Strip Sensors

Third-party testers have been using standard liquid point detection protocols to evaluate the polymer-strip sensors. These protocols are usually designed for mechanical or electrical switching devices that do not use chemical reactions like the polymer strips. It may be necessary to develop a protocol that takes into account the unique aspects of polymer-strip sensors. Ability to alarm and recover in a variety of environmental conditions should be assessed. The impact of repeated exposure of these sensors to fuel on response time and recovery time should also be evaluated.